PERFORMANCE AND EMISSION CHARACTERISTICS OF A DIESEL ENGINE OPERATING WITH BIODIESEL

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STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

The use of biodiesel as an alternative diesel engine fuel is increasing rapidly. However, due to technical deficiencies, they are rarely used purely or with high percentages in unmodified diesel engines. Therefore, in this study, biodiesel is used as alternative fuel in a diesel engine. The tests were conducted on a typical four-stroke, four cylinders, water-cooled, direct-injection diesel engine. The effect of test fuels on engine torque, power, brake specific fuel consumption, brake mean effective pressure, and CO, CO2, NOx and HC emissions was investigated. The experimental results showed that the performance of diesel engine was improved with the use of the biodiesel compared to diesel fuel. Besides, the exhaust emissions for biodiesel were fairly reduced.

ABSTRAK

Global biodiesel sebagai bahan bakar enjin diesel alternatif meningkat dengan cepat. Namun, kerana kekurangan teknikal, ia jarang digunakan secara asli atau dengan peratusan yang tinggi pada enjin diesel diubahsuai. Oleh kerana itu, dalam kajian ini, biodiesel digunakan sebagai bahan bakar alternatif di dalam enjin diesel. Ujian dilakukan pada empat-stroke khas, empat silinder, mesin air-cooled, direct injection diesel. Pengaruh bahan bakar uji pada torsi enjin, daya, penggunaan bahan bakar khusus rem, rem bererti tekanan berkesan, dan CO, CO2, NOx dan pembebasan HC diteliti. Keputusan kajian menunjukkan bahawa prestasi enjin diesel dipertingkatkan dengan penggunaan biodiesel berbanding diesel. Selain itu, pembebasan gas buang untuk biodiesel sudah cukup berkurang.

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LIST OF FORMULAE

$P = 2(\pi) \times (N) \times (T)$

Fuel consumption rate = ρ x Q

BSFC = Fuel consumption rate / Power

BMEP = $4 (\pi) \times (T) / Vd$

Φ = Stoichiometric fuel to air ratio / actual fuel to air ratio

LIST OF SYMBOLS

Φ	Equivalence ratio
B100	Neat biodiesel
B20	20% of biodiesel
CO	Carbon monoxide
CO_2	Carbon dioxide
HC	Hydrocarbon
N_2O	Nitrous oxide
N	Engine speed
NO_x	Nitrogen oxide
P	Power
p	Fuel density
Q	Fuel volume flow rate
T	Torque
Vd	Engine displacement volume

LIST OF ABBREVIATIONS

BDC	Bottom dead centre
BMEP	Brake mean effective pressure
BSFC	Brake specific fuel consumption
CI	Compression ignition
DI	Direct injection
EVC	Exhaust valve closing
HHVs	Higher heating values
IDI	Indirect injection
IVO	Inlet valve opening
TDC	Top dead centre

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Global air-pollution is a serious problem. Much of this pollution is caused by the use of fossil fuels for transportation. Therefore, engine manufacturers have designed alternatively fueled engines and fuel systems, which provide sufficient power while staying within regulatory emission-limits. At the same time, a great deal of research and development on internal-combustion engines has taken place in finding an appropriate fuel. Many researchers have concluded that biodiesel holds promise as an alternative fuel for diesel engines. Therefore, biodiesel can be used in diesel engines with few or no modifications. Diesel-fuel blends with biodiesel have superior lubricity, which reduces wear and tear on the diesel engine and makes the engine components last longer.

Biodiesel has a higher cetane number than petroleum diesel fuel, no aromatics, and contains 10–11% oxygen by weight. These characteristics of biodiesel reduce the emissions of carbon monoxide (CO), and hydrocarbons (HC), in the exhaust gas compared with diesel fuel. However, NOx emissions of biodiesel increase because of combustion and some fuel characteristics. The fuel properties of biodiesel such as cetane number, heat of combustion, specific gravity, and kinematic viscosity influence the combustion and so the engine performance and emission characteristics because it has different physical and chemical properties than petroleum-based diesel fuel.

Dr. Rudolf Diesel invented the first diesel engine in 1892 and it was designed to run on a number of fuels including vegetable oil. He developed the diesel engine to run on vegetable oil and commented that it would help considerably in the development of agriculture of the countries that use it. He demonstrated his engine at the World Exhibition in Paris in 1900 and described an experiment using peanut oil as fuel in his engine.

Biodiesel has actually been around for around 100 years but the cheap availability of petroleum fuel has made it the choice for diesel fuel. But now that petrodiesel prices have risen to such a high level, it's becoming affordable to use biodiesel. And it's becoming very popular in many countries across the globe.

1.2 PROBLEM STATEMENT

There are two problem statement in that has to be solved in this research. First is the prediction of the engine performance and exhaust emissions of diesel engine using biodiesel fuel and second is how the inputs affect the outputs of engine.

1.3 PROJECT OBJECTIVES

There are two main objective in that has to be achieved in this research. First is to investigate the performance and emission characteristic of a diesel engine operating with biodiesel and second is to investigate the different performance of biodiesel and diesel fuel.

1.4 PROJECT SCOPES

There are four main scopes in this research. First is four cylinder diesel engine installations. Second is installation of required instrumentation. Third is engine testing at various engine speed and lastly is collect all the performance and emission characteristic from the literature.

1.5 THESIS ORGANIZATION

This thesis consists of five chapters raging from chapter 1 to chapter 5. Chapter 1 gives an overview of the study conducted. It also included with objective, scope of the project and problem statement. Chapter 2 reviews the previous research works that was conducted by other people. All the relevant material including technical paper, journals, and books taken from those researches will be discussed in this chapter. Chapter 3 is the methodology. This chapter is about the method used and the progress of the project. It will discuss about the experiment conducted and flow in details of this research. Result of the experiment conducted and discussion of it will be discussed in chapter 4. Chapter 5 which is the last chapter concludes the entire thesis.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter covers the recent review of diesel engine powered with biodiesel research activities are presented here. All the studies are mainly focus on the performance and emissions characteristic for the diesel engine operating with biodiesel and comparison to conventional diesel engine.

2.2 DIESEL ENGINE

2.2.1 History

Although the history of the diesel engine extends back into the closing years of the 19th century when Dr Rudolf Diesel began his pioneering work on air blast injected stationary engines, and in spite of the dominant position in now holds in many application, it is today the subject of intensive development and capable of improvements.

Before 1914, building on the work of Dr Rudolf Diesel in Germany and Hubert Akroyd Stuart in the UK, the diesel engine was used primarily in stationary and ship propulsion applications in the form of relatively low speed four-stroke normally aspirated engines.

The 1914-18 war gave considerable impetus to the development of the high speed diesel engine with its much higher specific output, with a view to extending its application to vehicles. Although the first generation of road transport engines were undoubtedly of the spark ignition variety, the somewhat later development of diesel engines operating on the self or compression ignition principle followed soon after so that by mid 1930s the high speed normally aspirated diesel engine was firmly established as the most efficient prime mover for trucks and buses.

2.2.2 Classification

The major distinguishing characteristic of the diesel engine is the compression-ignition principle, i.e. the adoption of a special method of fuel preparation. The compression ignition (CI) engine operates with heterogeneous charge of previously compressed air and a finely divided spray of liquid fuel. The latter is injected into the engine cylinder towards the end of compression when, after a suitably intensive mixing process with the air already in the cylinder, the self ignition properties of the fuel cause combustion to be initiated from small nuclei. These spread rapidly so that complete combustion of all injected fuel, usually with air-fuel ratios well in excess of stoichiometric, is ensured. There are two broad categories of combustion systems:

(a) Direct Injection (DI) Systems

The fuel is injected directly into a combustion chamber formed in the cylinder itself, i.e. between a suitably shaped non-stationary piston crown and a fixed cylinder head in which is mounted the fuel injector with its single or multiple spray orifices or nozzles.

(b) Indirect Injection (IDI) Systems

Fuel is injected into a prechamber which communicates with the cylinder through a narrow passage. The rapid transfer of air from the main cylinder into the prechamber toward top dead centre (TDC) of the firing stroke promotes a very high degree of air motion in the prechamber which is particularly conducive to rapid fuel-air mixing.

Two-stroke engines

In two-stroke engines combustion occurs in region of top dead centre (TDC) of every revolution. Gas exchange also has to be affected once per revolution in the region of bottom dead centre (BDC) and with minimum loss of expansion work of the cylinder gases following combustion. This implies that escape of gas from the cylinder to exhaust and charging with fresh air from the inlet manifold must occur under the most favourable possible flow conditions over the shortest possible period.

Four-stroke engines

The vast majority of current diesel engines operate on the four-stroke principle in which combustion occurs only every other revolution, again in the region of top dead centre (TDC), and with the intermediate revolution and its associated piston strokes given over to the gas exchange process. In practice the exhaust valve(s) open well before bottom dead centre (BDC) following the expansion stroke and only close well after the following top dead centre (TDC) position is reached. The inlet valve(s) open before this latter TDC, giving a period of overlap between inlet valve opening (IVO) and exhaust valve closing (EVC) during which the comparatively small clearance volume is scavenged of most of the remaining products of combustion. Following completion of the inlet stroke, the inlet valve(s) close well after the following bottom dead centre (BDC), after which the 'closed' portion of the cycle, i.e. the sequence compression, combustion, expansion, leads to the next cycle, commencing again with exhaust valve opening (EVO). Figure 2.1 below shows the mechanism of 4-Stroke Engine

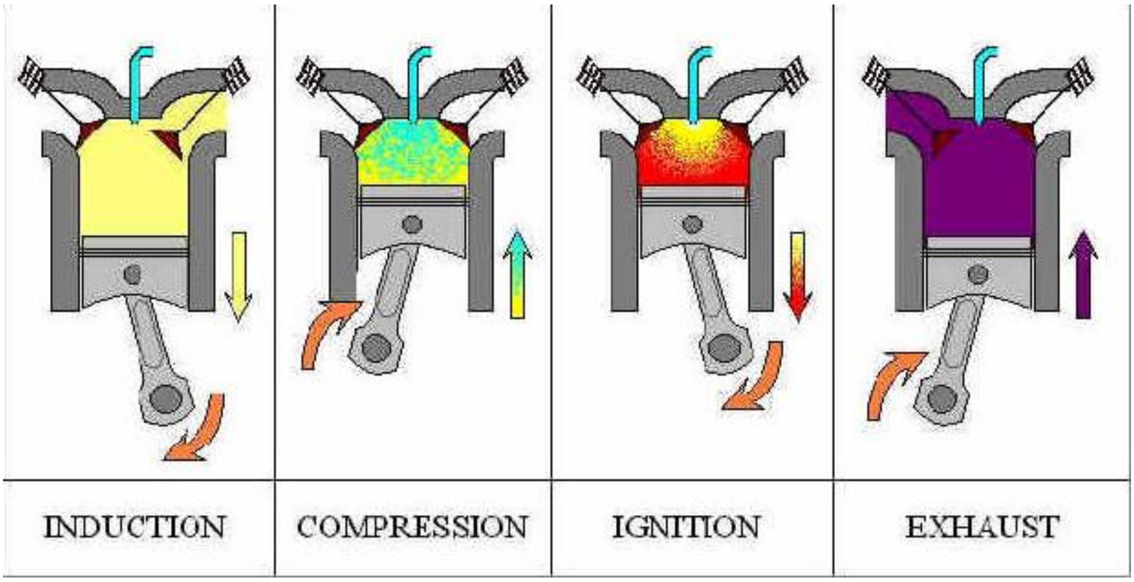

Figure 2.1: Mechanism of 4-Stroke Engine

- Induction stroke

The piston is at top dead center at the beginning of the intake stroke, and, as the piston moves downward, the intake valve opens. The downward movement of the piston draws air into the cylinder, and, as the piston reaches bottom dead center, the intake valve closes.

Compression stroke

The piston is at bottom dead center at the beginning of the compression stroke, and, as the piston moves upward, the air compresses. As the piston reaches top dead center, the compression stroke ends.

- Ignition stroke

The piston begins the power stroke at top dead center. The air is compressed. At this point, fuel is injected into the combustion chamber and is ignited by the heat of the compression. The expanding force of the burning gases pushes the piston downward, providing power to the crankshaft.

- Exhaust stroke

  As the piston reaches bottom dead center on the power stroke, the power stroke ends and the exhaust stroke begins. The exhaust valve opens, and, as the piston rises towards top dead center, the burnt gases are pushed out through the exhaust port. As the piston reaches top dead center, the exhaust valve closes and the intake valve opens.

The main advantages of the four-stroke cycle over its two-stroke counterpart are:

(a) The longer period available for the gas exchange process and the separation of the exhaust and inlet periods-apart from the comparatively short overlap-resulting in a purer trapped charge.

(b) The lower thermal loading associated with engines in which pistons, cylinder heads and liners are exposed to the most severe pressures and temperatures associated with combustion only every other revolution.

(c) Easier lubrication conditions for pistons, rings and liners due to the absence of ports, and the idle stroke renewing liner lubrication and giving inertia lift off to rings and small and large end bearings.

2.3 BIODIESEL

2.3.1 Definition

Biodiesel is defined as the mono-alkyl esters of fatty acids derived from vegetable oils or animal fats. It’s known chemically as a 'methyl ester'. In other terms, when a vegetable oil or animal fat is chemically reacted with an alcohol to produce a new compound that is known as a fatty acid methyl ester, that product is called biodiesel.

2.3.2 Biodiesel and its properties

The use of biodiesel has grown dramatically since the US Congress first provided an incentive the 1998 Energy Conservation and Recovery Act which allows federal and state fleet managers to meet the 1992 EPACT alternative fuel vehicle acquisition requirements by using biodiesel added to petroleum diesel at blend concentrations of 20% by volume or higher.

According to the National Biodiesel Board, the US production of biodiesel grew from 500,000 gallons in 1998 to 75 million gallons in 2005 and is estimated to have reached 150 million gallons in 2006 [1].

As of late April 2006, according to the National Biodiesel Board, there are 65 biodiesel plants currently in operation with a reported total maximum annual biodiesel production capacity of 395 million gallons [2]. 58 biodiesel plants are currently under construction or expansion with a reported total annual production capacity of 714 million gallons coming on line in the next 18 months, and an additional 36 plants representing 755 million gallons of maximum annual production capacity are reportedly beyond the planning stage, but not yet under construction [3].

About two-thirds of the existing and planned biodiesel production capacity is based on the dedicated use of soybean oil as the principal feedstock. This is consistent with the fact that much of the existing biodiesel production capacity is located in Midwestern states such as Iowa, Illinois, Minnesota and Ohio which also are large agricultural producers of soybeans that have been experiencing excess production capacity, product surpluses, and declining prices [4].

It is important to place the scale of biodiesel production and usage into perspective. In 2004, total on-road diesel fuel consumption amounted to 37.1 billion gallons or 2.4 million barrels per day [5]. At 75 million gallons, current domestic biodiesel production constitutes less than 0.2% of on-road diesel demand.

In September 2005, biodiesel usage was largely limited to rural areas and to demonstration programs sponsored by government agencies and private industry. It is currently being used in transit bus and heavy-duty truck fleets operated by private organizations as well as by municipal, state, local, and federal government agencies [6].

In February 2002, ASTM International issued ASTM D6751 which established specifications that neat biodiesel (B100) must meet as a blending component in petroleum-based diesel fuel in concentrations of up to 20% by volume [7]. These specifications help to ensure minimum product qualities by setting bounds on the biodiesel production process with respect to the completeness of the esterification reaction process, the removal of glycerin, catalyst and alcohol, and the absence of free fatty acids.

Biodiesel properties are a direct function of the carbon chain length and proportion of saturated versus unsaturated fatty acids present in the fuel plus the presence of additives. Biodiesel made from feedstocks that contain highly saturated fatty acids (such as yellow grease, beef tallow, palm and coconut oil) tend to exhibit high cloud and pour points, high cetane number, and better stability. Biodiesel made from feedstocks with high polyunsaturated content (such as soy and sunflower) have low freezing points, lower cetane number and poor stability [8].

The Table 2.1 below compares selected properties of typical neat biodiesel and current, typical low sulfur diesel. In general, biodiesel has a higher cetane rating than typical petroleum diesel fuel. It also contains 11% oxygen by weight. The minimum flash point (a measure of fire safety) for biodiesel is higher than for diesel to ensure that any excess alcohol used in the manufacturing process has been removed. Furthermore, the viscosity of biodiesel tends to be higher than that for typical diesel fuel.

The energy content of neat biodiesel is 8% lower (on a gallon basis) compared to typical petroleum-derived diesel, so some reduction in fuel economy and power can be expected with fuels containing biodiesel. But, users of B20 or lower blends in fleet demonstration tests generally report little noticeable reduction in vehicle performance and fuel economy [9].

Table 2.1: Selected Properties of Diesel and Biodiesel Fuels

Fuel Property	Diesel	Biodiesel
Fuel Standard	ASTM D975	ASTM D6751
Lower Heating Value,Btu/gal	~129,050	~118,170
Kinematic Viscocity, @ 40°C	1.3-4.1	4.0-6.0
Specific Gravity kg/l @ 60°F	0.85	0.88
Density, lb/gal @ 15°C	7.079	7.328
Water and Sediment, vol %	0.05 max	0.05 max
Carbon, wt %	87	77
Hydrogen, wt %	13	12
Oxygen, by dif. Wt %	0	11
Sulfur, wt % *	0.05 max	0.0 to 0.0024
Boiling Point, °C	180 to 340	315 to 350
Flash Point, °C	60 to 80	100 to 170
Cloud Point, °C	-15 to 5	-3 to 12
Pour point, °C	-35 to -15	-15 to 10
Cetane Number	40 to 55	48-65